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Application of concrete filled mats for fixing underwater slope

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Abstract

In this article the researchers offer to use concreting technology with textile mats for fixing underwater slope. The description of this technology and economic choice feasibility compared to other known solutions is given. Also, it is noted that the use of such technology is limited in areas with heavy ice conditions on water bodies. In this regard the need for scientific substantiation of mats parameters based on hydrometeorological conditions is indicated. The importance of conducting research in the laboratory and field site is noted. The results of field trials to assess the impact of ice fields on the selection of structural and technological characteristics of fixing the slope using textile mats in carrying out underwater concreting are given.

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Keywords: Bank stabilization; Hydraulic structures; Concrete filled textile mats; Work execution; Ice force.

1. Introduction

Building and reconstruction of fixed slopes at hydraulic structures are often subjected to water and sometimes water flow effects [11, 20, 22]. When traditional bank-protection structures from stone, mass and prefabricated concrete are used for construction and installation works the water flow is changed by coffer dams. All the works are executed without water, thus it leads to cost increase and prolongs construction period [1, 13, 18].

The use of up-to-date composite materials [8] such as concrete filled textile mats makes it possible to avoid installing coffer dams for the water flow change [3]. The mats [4, 16, 17] consist of two joined high-strength woven fabrics that constitute the formwork. Due to the flexible woven spreaders the thickness of the formwork can change. The space between two woven fabrics on the protected slope is filled with self-compacting concrete mix [21]. While

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gaining strength concrete is protected by textile woven fabrics from weather effects and washing out by the water flow. Thus, the design features of textile mats allow performing underwater slope protection works without decreasing the reliability of the structure [19].

Concrete filled textile mats have been used in construction over 30 years, but until nowadays they have been used basically in the areas with mild climate in Europe, see Picture 1. From 2010 to 2015 more than 500 000 m^2 of slopes were strengthened with concrete filled textile mats on the territory of Russia, see Picture 1 [4, 5].

At designing the existing structures the impact of ice fields was not taken into account as the structures are located in the areas without ice at all or the level of ice drift is lower the fixing section and the mats are used for the protection from wind-wave effects.

In order to expand the application area of concrete filled textile mats it seems to be of current interest to make the research on the possibility of using them in the areas with heavy ice conditions.

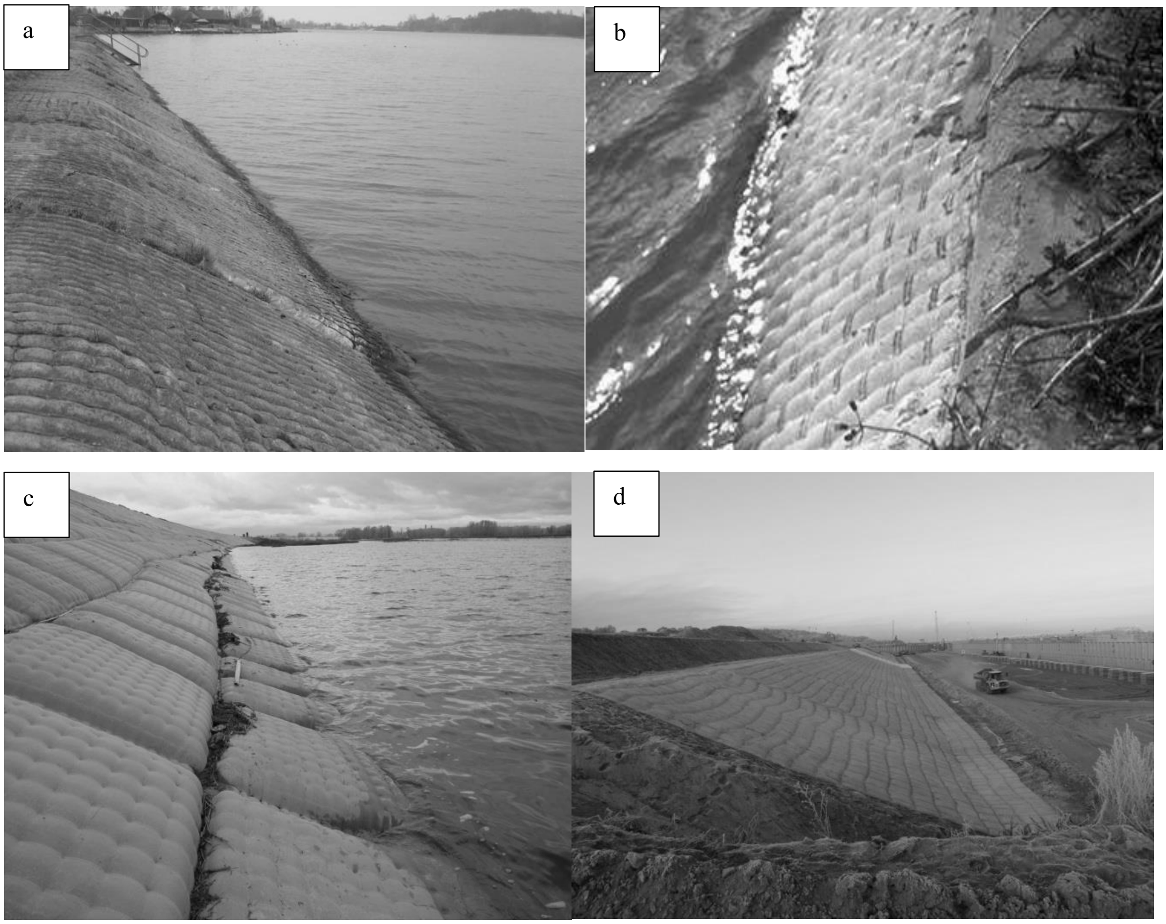

Fig. 1. The use of concrete filled textile mats. (a) - Lake Banter, Germany, 1977; (b) - Imperial de Aragones Canal, Spain, 1973; (c) - Bridge Crossing Kirovsky, Russia, 2012; (d) - Kuzminsky Waterworks, Russia, 2014.

2. Research

To evaluate the possibility of using concrete filled mats in the areas with heavy ice conditions the researchers suggested the idea of using two research groups:

- evaluation of the economic feasibility and expenses for fixing underwater slopes with concrete filled mats;
- conducting the research on the reliability of the offered construction decisions in the zones of possible ice impact.

We have sorted out and analyzed the bank protection structures that have been built and designed by us during the latest five years in the European part of Russia in order to evaluate technical and economic indexes of concrete filled mats and to compare them with other types of fixing slopes [2, 6, 7, 9]. Economic index is characterized by data given in Picture 2, while technological effectiveness is shown in Picture 3. Concrete filled mats (1), mesh structures (2), multi-purpose flexible protecting concrete mats (3), reinforced concrete slabs (4) have been analyzed. The calculation from ₽/m^2 to €/m^2 is performed with the ratio 1:57. As the parameter of technological effectiveness we assume the square of the slope that was fixed during eight-hour work shift.

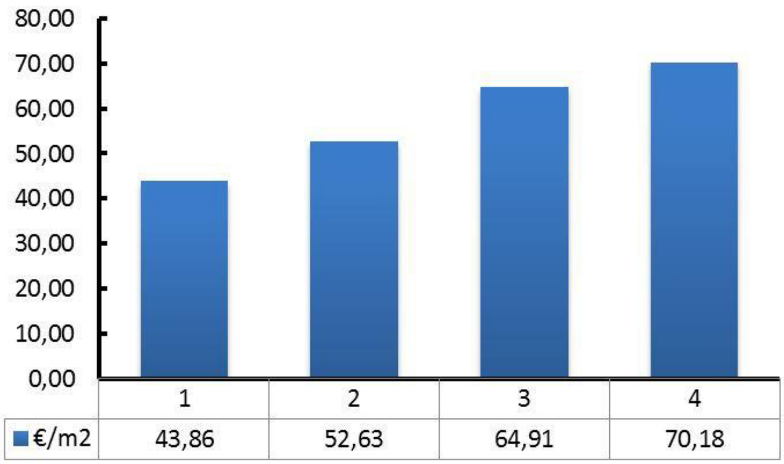

Fig. 2. Comparison of work costs depending upon the type of fixing.

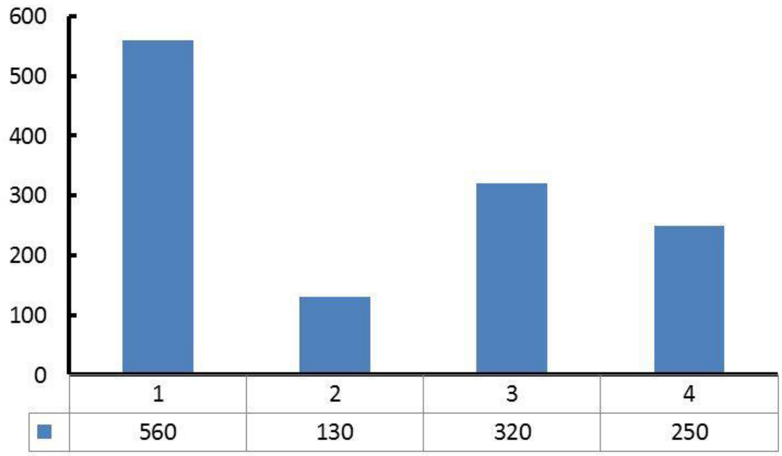

Fig. 3. Technological efficiency of different types of slope fixing.

The reliability of the structure was evaluated in the laboratory and field site. Field works were done on the test site of Saratov Reservoir [1], Picture 4. The water gauge station was arranged within the limits of the test site.

The concrete mats with typical thickness of 10.00cm, 20.00cm and 30.00cm were chosen for testing. On the basis of function and construction features of mats two sections on test site were allocated. In section №1 the mats were stacked with the width of 5.0m along the whole length of the slope. It corresponds to the working conditions of the bank protecting structure right after placing the mats in the designed position. In section № 2 the mats were stacked with the width of 60cm and 120cm that depended upon the width of one fixing element. Every element was separated from the other by threading along the height. Section № 2 simulated the conditions under which the connections between the fixing elements destructed after long operation period.

Fig. 4. View on the test site (February-March, winter of 2015). The ice is within the limits of the middle part of the fixed slope. The ice thickness is 69cm.

During the observation period at the water gauge station the state of the ice field was assessed, i.e. thickness, level and outdoor air temperature. The state of the ice was observed twice a week (on Wednesday and Sunday). Temperature and thickness of ice field during the winter of 2014-2015 are given in Table 1. The freezing-over on the river lasted four months. Active ice growth was observed during the first two weeks of stable frost in December at the temperature of 10°C below zero. Visual inspection revealed the water freezing and the adfreezing of ice with the concrete mats. The ice break-up started on the 20th of March.

Before starting any works the geodetic connection of mats in space was performed. The following was established after the ice break-up:

- the mobility of mats of 60x120cm in size and the average thickness of 10cm separated from each other during the site arrangement was observed, the mobility value was 7÷12mm towards the reservoir;
- the abrasion of concrete layer to the thickness of 2÷3mm was noticed in the zone with the removed upper cloth and the mats with the average thickness of 30cm that could be explained by their considerable protrusion from the general slope fixing plane;
- in other zones the deformations and destructions were not observed.

Table1. Indexes got during the observation period at the water gauge station.

Indexes	2014		2015			
	XI	XII	I	II	III up to 10	III after 10
Average air temperature, °C	1.6	-6.5	-10.1	-9.2	-2.6	3.5

Average air temperature at night, °C	-1.6	-8.7	-12.8	-13.7	-7.5	2.3
Minimum air temperature, °C	-13	-16	-24	-25	-19	-12.7
Maximum ice thickness observed, cm	-	40	50	53	69	-

3. Conclusion

On the basis of the research conducted in 2014-2015 the following conclusions can be made:

- The chart analyses (Picture 2 and 3) prove that the textile mats are the most cost and technologically efficient for fixing underwater slopes. The value of cost efficiency is about 13%;
- The observations make it possible to conclude that the ice thickness on the testing site in winter of 2014-2015 was 69cm. The maximum design load on a mat from the ice field was 0.62t/m^2 whereas the moving force of ice was 0.49t/m^2. The movements of some elements of a mat weighing 350kg were 7÷12mm. The elements of mats of larger weight did not deform. The destruction of concrete mats was not observed in all sections;
- It is possible to use concrete filled mats under the conditions of ice impact. The thickness of a mat and the characteristics of concrete to fill it should be chosen taking into account the ice conditions and in accordance with the instructions worked out on the basis of the conduced research.

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